THE PROGRESS IN FOREST ENTOMOLOGY AND PROTECTION AGAINST FOREST INSECTS

FROM

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THE PROGRESS IN FOREST ENTOMOLOGY

By the Division of Forest Insects, Bureau of Entomology

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The progress of forest entomology in this country has been intimately associated with the broader problem of forest protection and to some extent with forest management. The control of insect outbreaks or the prevention of losses from insect attack has been the stimulus for research aimed at accomplishing these ends. Investigation of forest insects and the development of control methods are a function of the Bureau of Entomology; the application of control methods, that of the Forest Service and of other land-administering agencies.

IMPORTANCE OF FOREST INSECTS

There is a continuous attrition in our forests from the activities of many different kinds of insects. All stages in the development of the stand, from the seedling to the mature plant, are liable to insect attack at one time or another and in some years even the developing seed crops are destroyed. In virgin timber stands, particularly those which are overmature, a normal loss is going on steadily as the result of insect activity and decay, but such loss for the most part is offset or, in some cases, exceeded by growth. Counterbalancing of growth against loss obviously results in no marked change in the forest capital. On the other hand, epidemic insect outbreaks occurring from time to time definitely deplete the forest capital to such an extent that long periods are required for eventual replacement. For instance the western pine beetle in southern and central Oregon, during the past 10 years, has caused a net depletion of the ponderosa pine stand amounting to 2,240 million board feet. One typical section on the Klamath Indian Reservation carrying a stand of 11,074,000 board feet in 1921, lost 3,875,000 board feet through barkbeetle attack during the period 1921–32. The growth, which was only 48 percent of normal due to drought and a defoliation by the Pandora moth, amounted to 294,000 board feet, leaving a net loss for the 11 years of 32.2 percent of the stand.

The total losses in the United States from all sources have been variously estimated at $100,000,000 to $150,000,000 a year. This includes depredations by such insects as the mountain pine beetle, the Black Hills beetle, the western pine beetle, the pine butterfly,

the spruce budworm, the hemlock looper, the gipsy moth, and losses to the felled log, sawn lumber, and finished wood products in use. A considerable portion of this loss is unavoidable, just as losses from lightning or windstorms are unavoidable. On the other hand, much of it can be prevented and will be so in the future through silvicultural practices, proper management, and direct control.

With mature timber one of the largest single items of loss results from activities of bark beetles. Actual surveys in our western forests indicate that 5 billion to 6 billion feet are destroyed annually by these insects. In lodgepole forests in and surrounding the Yellowstone National Park tremendous losses have occurred. It has been conservatively estimated that during the past 10 years these have amounted to 2,620 million board feet. In one year over 12 million trees were killed. During the last 20 years most of the mature lodgepole forests in regions 1, 4, and 6 have been completely destroyed or are in the process of destruction by the mountain pine beetle. If this is an exmple of what is to be expected in the future, we can assume that lodgepole stands, once they have reached maturity, must be so managed as to be harvested before the beetles play the part of lumbermen.

A recent survey indicates that the forest losses in the State of California due to bark beetles were at least 2¼ times as great in 1931 as they were on an average for the past 10-year period. This average figure has been placed at 500,000,000 board feet. This would indicate a state-wide loss of 1,125,000,000 board feet of merchantable timber. At a purely commercial stumpage rate this represents a loss of nearly $6,000,000, not taking into account the manufacturing value of the lumber, which is an asset going to the region where it is produced. Where these losses deplete the fine old forests that are being preserved as exhibits in the national parks and around recreational areas, they take on a value that is less tangible but undoubtedly much higher than in purely commercial timber.

Defoliating insects likewise destroy considerable bodies of mature timber. These outbreaks, however, usually appear at rather long intervals and are of short duration. An exceptional instance is that of the spruce bud worm in the northeastern United States and Canada, which ravaged the spruce and fir forests for a period of 10 years (from 1910 to 1920) and it has been estimated that in spruce-fir types of Maine, Ontario, Quebec, and New Brunswick from 40–70 percent of the timber was destroyed and that the equivalent of more than 25 years' pulpwood supply for current annual American paper requirements was lost. Or certain species, even if they do not kill the timber, cause a cessation or reduction of growth which may increase the rotation period of the stand from 5 to 10 years or more. Such defoliations may be local and confined to only a single species of tree or they may spread over enormous areas involving several species. The most recent outbreak of the Pandora moth in the ponderosa-pine stands of southern Oregon occurred between 1918–1925 and covered approximately 400,000 acres. Growth measurements from plots in this area showed that for a period of 11 years the normal forest growth on this area was reduced an average of 32 percent or a loss of increment of approximately 100 million board feet.

The northern white pine is subject to severe insect depredations during the early stages of its growth. The Pales weevil frequently

kills a high percentage of the natural reproduction and of the young trees set out in plantations, making it an unsafe practice to do any planting in the vicinity of cutting. After the seedling white pines become well established and until they are 25 years old the plantations and natural stands are subject to severe damage by the white-pine weevil, unless proper precautionary measures are taken. The commercial value of thousands of acres of northern white-pine plantations has been destroyed by this insect, definitely indicating that it is unprofitable to attempt to grow this pine on unsuitable soil or under conditions where some measure of protection is not assured.

It must be clearly understood that these figures for losses include normal as well as unusual drain in the forests. For example, surveys in the ponderosa pine type of California and Oregon tabulate all trees killed by bark beetles. Normally on the best sites but few trees die each year from this cause, say, 30–40 M feet board measure per section, while on poorer sites 50–100 M feet board measure may not be an unusual loss. In lodgepole stands normal losses are practically negligible so that any marked losses indicate abnormal conditions. The same applies to outbreaks of defoliators. They either cause little loss or widespread destruction.

The financial success of certain forest industries such as turpentining of the southern pines may hinge on the attack of insects. Improper methods of chipping result in the attack of a flatheaded wood borer which completely honeycombs the heartwood, lessening the tree's life as a turpentine producer and causing it to break off. Enormous losses have occurred from this source.

Forest plantations are particularly subject to the destructive activities of insects, chiefly because plantations usually consist of large blocks of a single species of tree. Then again many plantations are set out on soils that are not suitable for the species of trees used. Losses in northern white pine plantations in the Northeast and destruction of black-locust stands by the locust borer have, in a great measure, discouraged the planting of these valuable trees. There is a need for more knowledge and forethought in the setting out of forest plantations.

Insect-killed forests are a potential danger because of the existing fire menace. When extensive outbreaks of insects develop in forest types composed chiefly of one species of tree a high percentage of the stand may be destroyed. These standing dead trees go down in the course of a few years, making an almost impenetrable tangle of logs and tops. Under proper conditions a flash of lightning may set off the mass, resulting in a widespread conflagration almost impossible to fight. Past experience has shown that epidemics of the mountain pine beetle in lodgepole pine have been followed by fires more often than not.

The old snags of insect-killed trees scattered throughout our mature forests, which average for some areas as many as 10 per acre, stand for many years and greatly increase the cost, difficulty, and danger in fire control. Snag felling is required in many sales of national-forest timber, and many private operators have already adopted this regulation. The increased cost of control of fires which have spread from burning snags within fire lines would alone justify insect control even at a high cost.

Such a picture as that presented does not attempt to appraise insect losses in areas of great scenic value. The importance of the forest cover in national parks, game preserves, and recreational areas cannot be estimated in monetary values. Here the esthetic and protective values far exceed that of the commercial timber. Although not so directly appreciated by the visitor, one of the greatest attractions in these areas is the forest, as much of the natural beauty of parks, camp sites, etc., is in reality dependent upon a green forest cover. Trees also give protection to the birds and other animals. For these reasons insect depredations which mar the scenic beauty or destroy the protective value of the forest cover must be controlled regardless of cost.

There is another less appreciated aspect of the insect activities in our forests which each year is becoming increasingly important. In some forest types insects often are one of the chief limiting factors in successful management. Insects frequently "throw the monkey wrench", so to speak, into our well organized plans aimed at the production of continuous forest crops. In the western white and lodgepole pine types of the northern Rockies, bark beetles so affect the proportion of species in these stands as to convert the resulting forest into one of entirely different composition, often of inferior species, necessitating an entire reorganization of management plans.

All kinds of forest products from the moment the tree is felled and for many years after the wood is in use are subject to destruction by insects. Insects cause injuries in the living tree which show up as defects in the lumber, thus greatly reducing its value. Green sawlogs and storm-felled timber, green sawn and seasoned lumber, rustic construction, poles, posts, crossties and all manner of finished products from flooring to furniture are attacked. The losses in finished products are particularly heavy in that the cost of manufacture and replacement must be taken into consideration. However, with this type of damage it is much more practical to prevent losses. The most recent attempt to evaluate the losses from this source places the damage at from one half of 1 to 5 percent of the total value of various classes of products.[1]

DEVELOPMENT IN FOREST INSECT CONTROL

Control work against tree-killing bark beetles conducted by three Federal agencies—the Forest Service, the National Park Service, and the Bureau of Indian Affairs—and by private owners as well, has been an important part of the forest protection program in the Western States and incidentally illustrates marked progress in research and administration.

The first project was conducted by the Forest Service in the Black Hills National Forest, S.Dak., in 1906, when $2,700 was expended in an effort to check an epidemic of the Black Hills beetle. Since then many projects have been carried out, some of them covering extensive areas. A total of something over $1,000,000 has been expended through 1931. The annual expenditures from 1906 to 1921 were small—rarely over $20,000 and usually much less. Since 1922, with the fuller appreciation of the importance of the losses brought about through the activities of these insects, increasing amounts have been

[1] Statistical Bulletin No. 21, U.S.D.A.

spent each year for the protection of valuable timber stands. For the past three years the Forest Service has spent from $100,000 to nearly $200,000 annually, the Park Service from $40,000 to $50,000, and the Bureau of Indian Affairs from $10,000 to $20,000.

A candid appraisal of the results secured from the $1,000,000 spent in the control of tree-killing bark beetles has been made by the Bureau of Entomology.[2] In general it can be said that the value of timber saved through this work has been a great deal more than the total expenditures put into control.

Control work has been directed against seven species of bark beetles. Each of these beetles presents an entirely different problem in each forest region and in each forest type. Consequently every project must be considered separately, as attention must be given both to the administrative and to the entomological features. Control methods necessarily must be based upon information regarding the seasonal history and habits of the insects, and also upon certain conceptions and theories the validity of which can be proven or disproven only by trying out in practice. Early biological studies of these tree-killing bark beetles resulted in the adoption of certain control practices. These methods, although theoretically effective, were admittedly too expensive to adopt under all circumstances and it was recognized that much improvement was desirable. Even now and for some time in the future this type of work will be largely experimental in that uniformly good results cannot be guaranteed until a background of experience is developed. The increasing annual expenditures for control made it possible to experiment with new technique with the result that the present average cost per tree has been reduced by nearly half that of the average cost of a few years earlier.

The so-called "sun-curing method" is used in the control of the mountain-pine beetle in lodgepole pine in the vicinity of Crater Lake, Oreg. This was first tested in 1925 and 1926 and has been applied on an increasing scale up to the present time. It consists of simply felling and limbing the tree, allowing it to lie exposed to the sun for a few days, and then turning the other side of the log to the sun's exposure. The cost of treatment per tree in this park was reduced from $1.75–$2 to 40–50 cents, depending on accessibility and seasonal conditions.

Again, with the same beetle in the enormous lodgepole pine infestations in Yellowstone National Park and the surrounding national forests, a method was devised for burning the bark from the trees while standing. This effectively killed the beetles and cost in the neighborhood of 50 cents per tree when it was possible to get fuel oil into the forest by road. The former type of control cost in the same locality averaged $1.50–$2 per tree.

The possibilities of tree medication for the control of bark beetles have been experimentally tested for the past few years. This calls for the injection of chemicals into the sap stream of the tree which in turn will prevent the development of the bark beetle broods and do away with the costly operations of felling and barking or burning the tree. There appears to be much promise in this field but it is yet too early to be confident of results.

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[2] Journal of Forestry, vol. 29, no. 7, November 1931.

A series of tests are under way with certain oils and chemicals which will penetrate the outer bark of infested pines and kill the bark beetle broods. If a cheap material can be developed it will do away with the labor of peeling infested trees and subsequent burning of the bark—two phases of the methods now in use which add considerably to the expense and fire hazard of control projects. Several materials have been tried which promise to be quite effective in producing a kill if applied during the earlier stages of brood development. If the technique of application can be satisfactorily worked out and the cost of materials kept within reason, these experiments should represent a real contribution toward more effective methods and lower control costs.

COOPERATION BETWEEN THE BUREAU OF ENTOMOLOGY AND OTHER FEDERAL AGENCIES IN INSECT CONTROL

It has already been pointed out that forest insect control involves many technicalities based on an intimate knowledge of the habits of the specific insect causing the damage. It likewise involves a detailed knowledge of the topography of the lands under control as well as close contacts with local labor and transportation facilities, which information is only available to the administrative officers on the ground. Due to this combined requirement for technical, entomological, and administrative knowledge, cooperation has been a necessary essential in all past control work.

The responsibility for the investigation of insects affecting forests or, in other words, the discovery of the biological facts on which control rests has been invested by law in the Bureau of Entomology. This law further provides for the cooperation of the Bureau of Entomology with other Federal agencies charged with the protection of Government lands and with private timberland owners. Briefly, the instructions state that the Bureau of Entomology shall be responsible for conducting surveys and for giving specific recommendations for control at the request of other Federal agencies and for the assignment of an entomologist to the project during the period of control when conditions warrant. In actual practice the spirit of cooperation has exceeded the letter of the law. The Forest Service and National Park Service, as well as private owners, have aided the Bureau of Entomology by supplying field expenses or part of the salaries of entomologists engaged in control and the Bureau of Entomology has, from time to time, particularly in the case of the National Park Service, assumed more than its share of administrative duties. The chief handicap to the more successful conduct of such cooperation has been the lack of trained personnel in the Bureau of Entomology.

Another form of cooperation is that involving the joint treatment of intermingled or adjacent lands under different ownership or administrative agency. Insects are no more restricted by ownership boundaries than is fire, hence the necessity for coordinated suppression efforts. This need has been adequately and harmoniously met in the past by all Federal agencies. There is need of greatly strengthening this present effort, particularly by making available funds for coordinated attack when emergencies develop and for more adequate entomological supervision.

FOREST INSECTS AND FOREST MANAGEMENT

Forest entomology is not only a science of protection as emphasized in the foregoing discussion but one of prevention as well. It is obviously better to prevent outbreaks of insects from becoming destructive than to wait until they have gained such momentum as to make direct control necessary. This objective will be attained more fully in the future through proper silvicultural practices applied to the growing stands whereby unfavorable conditions for the development of the insects are maintained or greater resistance of the stand to insect attack is developed. To determine the necessary practices for this form of protection close cooperation between the personnel engaged in other phases of forest research and entomologists of the Bureau of Entomology has been developed at six of the Forest Service experiment stations and certain results have already been obtained.

The reforestation of abandoned farm lands and other waste lands in the Middle Atlantic and New England States has been materially retarded through the activities of the white-pine weevil as already mentioned. Northern white pine, a most desirable and fast-growing tree, has been more extensively used for this purpose than any other species. With the enormous increase in the acreage of susceptible material, the white-pine weevil has increased to such an extent that it has become a serious menace. A thorough study of the problem has indicated that if these plantations are confined to the better sites and the trees spaced not greater than 6 by 6 a profitable crop can be obtained regardless of weevil attack. More recently it has been found that, even in those stands which have been very severely injured, it is possible to carry out certain reclamation practices which will at least give a fair yield from stands which otherwise would be a total loss.

The production of spruce and fir pulpwood in the New England region is intimately associated with the activities of the spruce budworm. Recent investigations have shown that the mortality in various stands following attack of this insect is directly correlated with the vigor and the composition of the stand. In other words, if rapid growth and a low percentage of fir is maintained, the forest will be practically immune.

The woods practices of a decade ago in the naval-stores industry in the South resulted in extravagant losses from dry facing and windthrow. The latter frequently affected such a high percentage of the stand that the crop was abandoned. This windthrow was in a large measure the result of the weakening of the trees by an insect boring in the heart wood of the tree. It gained entrance to the tree through the faces in the turpentined timber. Investigation showed that this loss was preventable through the adoption of conservative practices which at the same time increased the yield of gum and greatly prolonged the period of operation on a given area.

Black locust, a fast-growing tree which has been extensively planted in recent years, particularly on poorer soils, for the purpose of checking erosion, suffers extensively from the attack of the locust borer. In many sections of the country it has been found impossible to secure satisfactory artificial stands. Often the value of the material may be reduced to a point where it is practically useless except for purposes of fuel. On the other hand, natural stands are rarely

injured. Recent investigations of this problem, although not yet completed, indicate that the vigor of the individual tree is the most important factor in regulating locust borer damage. Damage occurs in inverse relation to vigor—that is, the more vigorous the tree the less the damage and, furthermore, the borer itself cannot develop in vigorous trees. At present the application of these findings indicates that the solution lies in management through coppice and development of more vigorous strains for planting on waste lands.

For a number of years prior to the conclusion of recent studies the bronze birch borer was by some foresters regarded as a serious forest problem in the management of mixed hardwood stands in northern New England and the Lake States. It is of practically no importance in an uncut forest, except in one which is overmature and where general decadence has set in, but appears in great numbers coincident with the death of the trees left after partial cutting of the original stand. It has been shown that the changes in the physical factors of the environment brought about through the medium of logging are often such that trees left will succumb without the attack of either insects or fungi, and the borer plays only the role of a secondary factor in hastening post-logging decadence.

The application of these studies has indicated that selective logging in any forest which contains a large percentage of birch is a dangerous practice where more than 25 percent of the basal area of a stand is removed. Where cutting is heavier than this, factors of decadence, of which the bronze birch borer constitutes only a minor one, are such that losses will more than offset growth in the period following cutting.

Much progress has been made in recent years toward establishing sustained yield on both Federal and private timberlands in the ponderosa-pine type of California and Oregon. The management of these stands is based on an initial partial cutting, leaving a sufficient reserve of timber for future growth so as to enable a second cutting in from 30 to 40 years. Bark-beetle losses in these stands reserved for future growth have in certain areas not only offset all increment, but have reduced the original forest capital from 1 to 15 percent. Recent experiments have indicated the possibility of avoiding this loss by removing insect-susceptible trees in the initial cutting. These susceptible trees are those of slower growths which can be detected at the time of marking the timber for sale. Recent sales have been marked on this plan.

FOREST INSECTS AND FOREST PRODUCTS

Federal research into the damage and methods of prevention of insect losses to crude and finished products has resulted in great savings to the industry. Losses in this character of material can frequently be prevented by very simple means, such as prompt movement of the felled logs from the woods so as to avoid exposure during the period of insect activity, storing the freshly felled logs in water, or exposing them to direct sunlight during the summer months. At the mill or storehouse prevention can be accomplished by proper inspection, by segregation and classification of the stock of material on hand so as to insure that such material as the sapwood of hickory, walnut, or oak is not held under conditions subject to attack by powder-post

beetles. In the case of materials used in rustic construction, cutting at certain seasons of the year or treating with repellent sprays affords ample protection. Such information has been disseminated through letters and bulletins and personal contacts to such an extent that many mills and operators are fully aware of the possibilities of insect losses and many are adequately guarding against them.

BENEFICIAL FOREST INSECTS

All forest insects are not destructive. There are many species of beneficial insects known as predators or parasites—the former devour the host bodily, the latter usually feed within the body of the host. Occasionally these predators or parasites are the controlling factor in the decline of an outbreak of forest insects. A great deal has been learned about the handling and practical use of certain forms of these beneficial insects, particularly those preying on the gipsy moth. The predators and parasites of this species were introduced from Europe and Japan and established in this country with marked controlling effect on this destructive pest. The pine tip moth was accidentally introduced into the pine plantations of the Nebraska National Forest and for a number of years so retarded the growth of these trees that the abandonment of the use of pines as planting stock was seriously considered. In 1925 a few parasites of this tip moth were collected in Virginia and liberated at Halsey, Nebr. These took hold with remarkable rapidity, and by 1930 had destroyed practically 90 percent of their hosts, effecting satisfactory control of the tip moth. For the past 2 years the effect of this control has been clearly shown in the increased vigor and height growth of the trees. At the present time parasites of several destructive foreign pests such as the larch sawfly, the European pine-shoot moth, and the birch sawfly are being studied in Europe, with the idea of eventually controlling these pests in this country through the establishment of their enemies. There are great possibilities in this field which have hardly been touched.

INSECTS AND FUNGI

The interrelation of insects and fungi presents many interesting technical problems, the solution of which may have a very practical bearing on insect control. For several years the entomologists and pathologists have been cooperating in this field. It has been demonstrated that some of the most destructive species of bark beetles introduce fungi—so-called "blue stains"—into the tree when they attack it, and that these fungi play an important role in hastening the death of the tree and possibly in furnishing conditions necessary for the development of the beetle broods. In at least one case this blue stain alone is capable of killing the tree. It is not going too far to say that a more complete knowledge of the intricate relationships of insects, fungi, and the tree may lead to an entirely different conception of this whole problem and to better control—much as the determination of the interrelation of the mosquito and malaria parasite led to modern prophylactic methods in the control of malaria. There are many such complex interrelations between fungi and insects. For example, the sporadic dying of oaks in the southern Appalachians presents a complex of insects and diseases which we know little about

at this time. The same thing has recently been found to exist in the case of dying western white pine in Idaho and Montana, and in California a bark beetle and a fungus are instrumental in the widespread death of Monterey cypress planted for windbreaks, while throughout the Sierras another bark beetle and fungus are causing wholesale destruction of firs. These examples merely emphasize the complexity of the whole problem of forest research and the need of intensive and thoroughly coordinated investigational effort.

CONCLUSION

This brief general picture is intended to illustrate the more important activities of insects in our forests, the development of control methods and preventive silvicultural practices, as well as the dependence on research for continued improvements.

More adequate protection of Government-owned timberlands is desirable: (1) to reduce the losses in merchantable timber; (2) to insure protection of areas of scenic value; (3) under certain circumstances to curtail the development of a fire menace; and (4) to provide better insurance for timber-growing enterprises.

It might be said that fair progress has been made in the past 20 years in the field of forest entomology. For the most part the preliminary work having to do with the discovery, identification, and classification of the important forest insects has been completed. In fact, for many of the important species the life histories and habits have been pretty well worked out as well. However, there is need for a great deal more study into the fundamentals of insect ecology and physiology. We must know more of the interaction of the insects, the tree and the forest, and man's activities in the forest. It is altogether possible that such studies may lead to the prediction of outbreaks and consequent better control or prevention far beyond any possibilities we can see at present.

PROTECTION AGAINST FOREST INSECTS

By the Division of Forest Insects, Bureau of Entomology

The importance of insect activities in the growth and development of the forest from the time the trees are planted until they are harvested, and even to the products after they are put to use, has already been pointed out. To briefly recapitulate, insects cause enormous losses in mature stands of timber which are being held in reserve for future needs. They lower the yields and affect the rate of growth of developing stands. They frequently change the composition of the forest to such an extent that complete reshaping of the plan of management is necessary. They create serious fire hazards and take a varying toll from crude and finished forest products. On these grounds the consideration of insects in the forest is primarily a matter of protection to be secured through the early detection and suppression or the prevention of insect outbreaks, but also of equal if not greater importance is the matter of the necessary research for developing this protection. The ways and means of obtaining more adequate results in protection from forest pests is discussed in some detail as follows:

1. The prompt control of forest insect outbreaks when such control is economically sound in the broadest sense must be provided.

Just when, where, and how to do control, and at the same time secure maximum protection consistent with the economic or aesthetic values at stake, is the key to the entire problem.

The policy of letting nature work things out in her own way has some merit. Such a course of action at least involves a minimum of effort and cost. This policy of "letting nature take its course" is in fact the one that has been followed too often, with results that are all too evident. If we accept this as a course of action, we must also accept the probability of slow or sudden depletion of the older forests, which as they stand today are ripe and ready for the beetles. If we are willing to do this and wait for nature to replace these losses by the slow process of growing a new crop of trees, then the matter of taking any further steps to expand our present efforts can be dropped from consideration.

On the other hand if we were to launch out upon the policy of combating all threatening bark-beetle infestations everywhere, the cost would be enormous. One million dollars would be a very conservative estimate of what could be spent to advantage in California alone dur- the present winter and spring for the very good purpose of killing beetles that are destroying timber of high value; and in the lodgepole pine forest around Yellowstone National Park over $2,000,000 could be spent this spring. Such expenditures should of right be carefully questioned from all angles, and the plans for any large control projects governed both by economic considerations and the entomological factors which involve the prospects for successful results. Intelligent planning should therefore underlie the expenditure of both public and private funds for control jobs of this character.

There are two distinct classes of timberlands needing protection from insect pests—those where a present or future commercial value is

the chief consideration and those where the esthetic values are predominant. A third class, the so-called watershed or protection forest, need not be given consideration at this time except when the infestation threatens other timber of greater value. The commercially valuable timber includes that on lands of the national forests, Indian reservations, public domain and private lands. The timber needing protection because of its esthetic values lies in the national parks, State parks, and on small areas of the national forests devoted to recreational use.

A reasonable policy for forest insect protection has already been adopted by the National Park Service (A Forestry Policy for the National Parks, approved May 6, 1931). This adequately meets present needs and as it well illustrates both entomological and administrative considerations, it is quoted herewith.

Insect control policy.—It will be the policy to secure and maintain, so far as practicable, full protection from insect epidemics in areas of the following character within the national parks and monuments.

(1) Areas of intensive use, such as camp grounds.

(2) Areas of important scenic or esthetic attraction (unless the partial loss of the tree species attacked within a mixed stand will not materially affect the general appearance of the stand and its scenic or esthetic value, nor materially add to the fire hazard).

(3) Areas of prospective intensive use within the next 10-year period.

(4) Areas within the national park threatening protected areas within or outside the national park.

(5) Areas of unusual fire hazard.

(6) Areas set aside for study and research (unless natural agencies are to be left undisturbed).

Complete protection in the sense here used would call for removal of light endemic infestation in areas of intensive use.

With such insects as the mountain pine beetle in lodgepole pine and the Black Hills beetle in ponderosa pine, there can be no question but that every outbreak should be immediately controlled before it develops into a widespread epidemic costing often thousands of dollars.

Quite a different example is presented in case of the western pine beetle in Oregon and California. This beetle takes annually a small percentage of the stand and at intervals of some years a considerably larger percentage. The main objective in controlling the depredations of this beetle would be to prevent the peaks of this type of infestation developing and thus prolong the life of the existing stand over a longer rotation of gradual replacement; in other words, the objective would be to carry on a certain amount of maintenance control from year to year in an effort to keep the losses at the lowest possible status all the time.

With defoliating insects, it is possible to readily control them where the trees are accessible to high-powered pumping equipment such as along main highways. Within a few years it may be practical to use airplanes for dusting some of these infestations.

Under the above policy, remote areas of no special scenic value and not of high fire hazard, little used or seen by the public and not planned for intensive use within a reasonable period of years, may be omitted from insect control plans if they will not endanger control in adjacent areas, unless there are other special factors which make their protection from insects important.

In the national forests or other public lands where timber values are the main consideration, these values must be weighted against the probable future time of logging, the possibility of salvaging the insect-killed timber, the species of insect causing the destruction and the degree of virulence of the infestation. These considerations apply equally to private lands and it can be said in general private owners have more often taken the initiative in applying control than have the Federal agencies. It is obvious that with the intermingling of various classes of Federal and private timber each requiring different degrees of protection and the entomological technalities involved

closest cooperation is required for the successful conduct of control work. The means developed to meet these complex needs are discussed under "The Progress in Forest Entomology".

For the fiscal year 1933 there is available for insect control in Federal services as follows: Forest Service, $100,000; National Park Service, $50,000; and Bureau of Indian Affairs, $20,000. These funds are totally inadequate as evidenced by the call for extra money through various deficiency bills. It is conservatively estimated that in order to meet present needs for protection from forest insects $400,000 is needed annually by these agencies administering Federal lands. On the basis of this same degree of protection $200,000 should take care of insect outbreaks on private lands, and $15,000 on State-owned lands. This amount will only be adequate for a few years to come. As timber now economically inaccessible becomes more valuable, and as the recreational areas on the national parks are expanded, more and more of these insect outbreaks must be controlled.

2. A well-organized system of detection is necessary to—

(*a*) Avoid the introduction of injurious foreign insects;

(*b*) To detect outbreaks of native insects in the early stages in order that control work may be initiated when it is most effective and least expensive.

The need for taking every reasonable measure for the interception of foreign pests before they become established in the country is fully appreciated and the dire consequences that can follow such introduction are well illustrated by the destruction caused by the gipsy, browntail, and satin moths and the European pine shoot moth.

Early detection of insect outbreaks is obviously a prerequisite to control. The failure of certain control projects has been the result of tardiness in recognizing an active infestation or of incomplete information as to its virulence and extent. It is obvious that a well-executed system of detection, coupled with prompt action in control, will prevent the development of many bark-beetle outbreaks such as we are now witnessing and powerless to stem. Such a program is economical not alone because of the timber saved, but as well in the actual outlay of money for control. Throughout the western States cooperative detection systems have been set up between the Federal land administering agencies, States, private owners and the Bureau of Entomology. These so-called regional surveys are in various stages of perfection, depending on the values at stake, the degree of insect hazard and the funds available. These projects should be extended and carried to the point where the forest areas can be zoned according to their susceptibility to insect infestations, and each susceptible area rated according to values, whether for potential lumber or for park and watershed cover. This will give a basis for decision as to the areas that the owner or administrator should protect and the areas that will be deeded over to the insects when the advance guards of the epidemic appear and present claim to the timber.

3. An adequate program of forest research.

Research is absolutely essential to the perfection of all phases of the practical application of forest entomology, whether it be direct control, prevention, or the use of beneficial insects. The extent to which this application depends on the peculiar habits of each species of insect has already been pointed out in the section entitled "Progress in Forest Entomology". Through research direct control methods

against tree-killing bark beetles in the West have been gradually cheapened and made more effective. With other insects it has been found feasible to prevent their destructive activities by methods applied in the management of the stand. Research is also necessary to use beneficial insects to the best advantage. It has been demonstrated to be quite feasible to import beneficial insects from one country or section of a country to another, establish them, and obtain effective control through their activities.

A great deal of experimental work is needed to perfect methods of combating defoliating insects. At the present time the use of poison dust distributed from airplanes seems to be the most practical means of control but too little has been done in this line to speak with any authority. Satisfactory poisons have not been developed nor has the mechanical application over forested areas been perfected. Here again the spending of large sums of money on work that is not carefully planned and is lacking in definite objectives is open to question. Research must often proceed slowly, following the promising leads as they are uncovered and carefully checking results before they are given out. This type of work, therefore, offers the greatest possibilities for the discovery of new methods and short cuts to effective handling of the problem, and therefore deserves high priority in the future development of a balanced program.

The first appropriation specifically designated for research in forest entomology was made in 1902 to the Bureau of Entomology. It was $5,800. Since then gradual increases have been made to a maximum of $139,000 for the fiscal year 1931. (This does not include $104,530 expended on the gipsy moth project, which was combined with forest insect investigations about this time.) In that part of the appropriation applied strictly to forest insects some 50 percent is expended for extending service in control work to other Federal agencies and on intermingled private lands.

The needs for the satisfactory expansion of research in this field have been authorized by Congress in section 4 of the McSweeney-McNary Act of May 22, 1928 (45 Stat., 699). This provides for a gradual increase to a total of $250,000 which would take care of the most imperative studies for which some 5 years to come.

4. An educational program to make more effective objectives 1 and 2.

Although the Bureau of Entomology assumes responsibility for the decision as to when control is necessary and for the methods to be applied, it is obvious that the more thoroughly the local administrative officers understand these matters the better will be the results obtained. For this reason, the Bureau of Entomology has been devoting some effort to educational work among the field men of various agencies administering Federal lands. This field personnel in close contact with local conditions should be able to recognize insect outbreaks in the incipient stage and report to those competent to judge the seriousness of the situation. Consequently entomologists have been dispatched to many of the district ranger camps maintained by the Forest Service and to the instruction meetings of the National Park Service. Leaflets of instructions and reports have been prepared and disseminated through the administrative personnel, and many local contacts have been made with the field men of other agencies. There is need of much greater expansion of this work, and there should be available men specially designated to handle and enlarge this educational and extension work.

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